THE BORDEAUX AUTOMATIC TRANSIT CIRCLE : FIRST CATALOGUES, CURRENT AND FUTURE PROGRAMS

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Abstract. - The Bordeaux automatic meridian circle has been used for routine differential observations for three years. Current programs concern NPZT stars, faint nearby stars from the Gliese catalogue, Mars, Uranus, Neptune, Jupiter and Saturn satellites, and minor planets. From 1984 on, 5000 faint stars from the HIPPARCOS Input Catalogue will be observed.

1. INTRODUCTION

Since September 1980, the Bordeaux meridian circle has been working in a semi-automatic mode with visual setting of the instrument. From April 1983, the setting operation is also fully automatic and the only operator intervention is to enter the number of the star to be measured on the keyboard. A sophisticated program of automatic management of the observations should permit in a near future operating without operator if reliability of the whole system is convenient.

The observing sequence, fully controlled by an on-line computer (at present a PDP 11/45 working in time-sharing with other users) is roughly as follows :

a) From the internal star files the computer calculates the apparent place of the target star and the refraction correction, and the required setting angle. The instrument is at first rotated by a DC motor and gear wheel and clamped with an accuracy to better than 9'. Fine motion of the clamping system is then achieved with a stepping motor so that the accuracy of the setting angle is now 6". Finally, after a quick (3 seconds) declination circle reading, the computer gives the deviation to the desired setting angle and controls the presetting of the declination micrometer carriage so that the target star image finally appears at the center of the focal field with an accuracy of 1" (obviously only if the star coordinates found in the initial file are themselves this accurate).

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b) A digital time-shifting threshold detector associated with a time and magnitude window informs the observer about the presence of the star and automatically starts the tracking and measuring sequence and triggers at the same time the final declination circle reading. During the tracking (45-90 seconds), the photomultiplier supply is servoed for constant pre-amplifier output whatever star magnitude. The magnitude equation should thus be negligible.

The EMI 9789 B photomultiplier is associated in the tracking micrometer with a filter Schott GG 495 ; the effective wavelength is therefore about 5300 Å with a full width at half maximum FHWM = 600 to 800 Å. In front of the rotating knife-edge is mounted a focal diaphragm of diameter 20", enabling the observation of faint stars up to the visual magnitude 12.5.

Determination of positions are strictly differential and rigidly linked to the FK4 system in the declination range -25°, +82°. Observations of circumpolar stars are possible, but have thus far not been made.

2. RE-OBSERVATION OF THE NPZT PROGRAM

The Northern Photographic Zenith Tube program, already observed at Bordeaux (Mazurier *et al.* 1973) within the frame work of an international cooperation completed in 1980 (Yasuda *et al.* 1982) was observed again during the period 1980.7-1983.5 (mean epoch 1981.9). 11200 observations were obtained for 1649 stars of that program, i.e. about 7 observations per star on an average. The mean square error for one observation was

$$0.11_2'' \text{ in } \alpha \text{ and } 0.16_3'' \text{ in } \delta.$$

The internal mean error on a Bordeaux position is therefore

$$0.04'' \text{ in } \alpha \text{ and } 0.06'' \text{ in } \delta.$$

2.1. Comparison with individual PZT catalogues

We have compared our second NPZT catalogue with the PZT catalogues of Hamburg, Postdam, Washington and Richmond.

For the Hamburg catalogue (Enslin 1983) with $\delta = +53°$, the differences, star by star, after reduction of the two catalogues at the same epoch by using the Hamburg proper motions, and elimination of the mean deviation (Fig. 2 for the 115 common stars) have dispersion of

$$0.06'' \text{ in } \alpha \text{ and } 0.11'' \text{ in } \delta.$$

The agreement in α is quite remarkable and leads one to state that the accuracy of each instrument is about 0.04". However, if this accuracy should be also available in δ for the Hamburg PZT, then the accuracy in δ of the mean positions obtained at Bordeaux would only be 0.10".

Comparison with the Postdam catalogue (Meinig 1983) with δ = +52° gives approximately the same standard deviation in the two coordinates (from 117 common stars), namely

0.10" in α and 0.10" in δ.

Concerning the Washington catalogue (Mc Carthy 1983) for the zone +39°, the comparison with Bordeaux in α shows a more prominent standard deviation with probably a periodic error $\Delta\alpha_\alpha$. In δ, if we eliminate 5 erratic stars near the edge of the PZT field, the standard deviation is 0.10", similar to that against the other catalogues (Fig. 1).

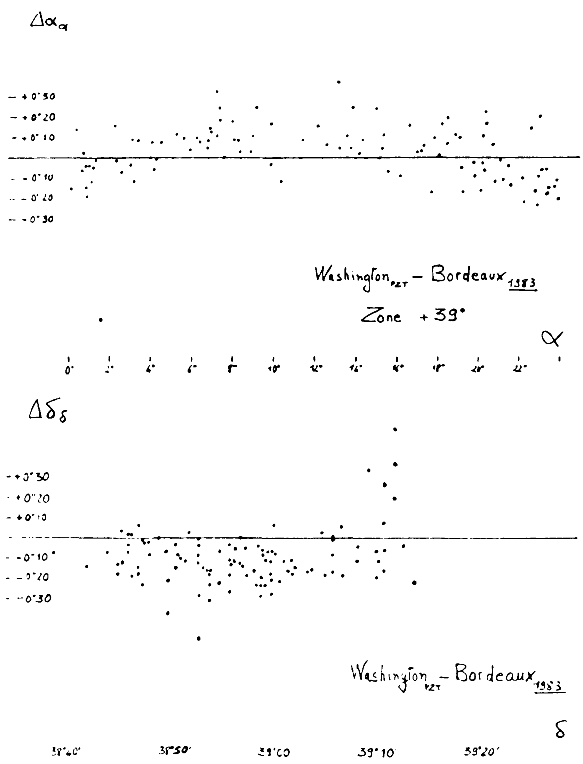

Figure 1. Washington P.Z.T. minus Bordeaux.

At last, the Richmond catalogue (Mc Carthy 1983) in the zone +25° shows good agreement with the Bordeaux results in right ascension (0.09"). But in declination there appears a very large systematic error $\Delta\delta_\delta$ (Fig. 3) the amplitude of which is ± 0.40" on the edges of the PZT field. The same type of error was already found in 1973 by comparing the positions in our first NPZT catalogue with the local catalogue in current use at Richmond. This effect seems to be combined with an error $\Delta\delta_\alpha$ which increases the discrepancy. (Let us note that our two catalogues were observed with quite different declination circles and reading systems.)

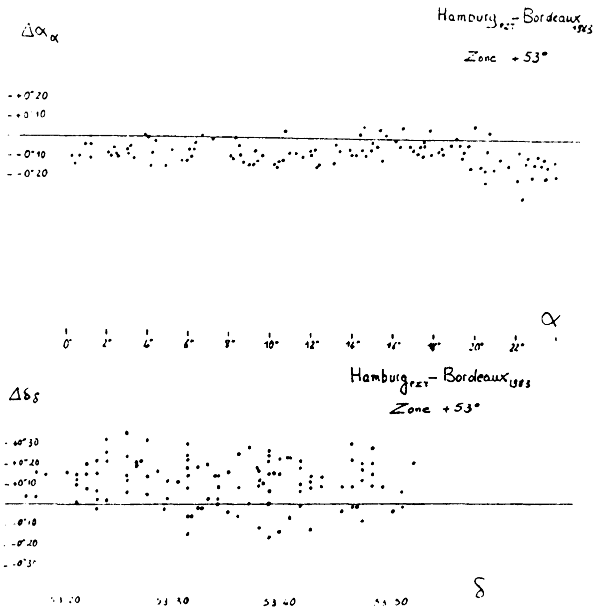

Figure 2. Hamburg P.Z.T. minus Bordeaux.

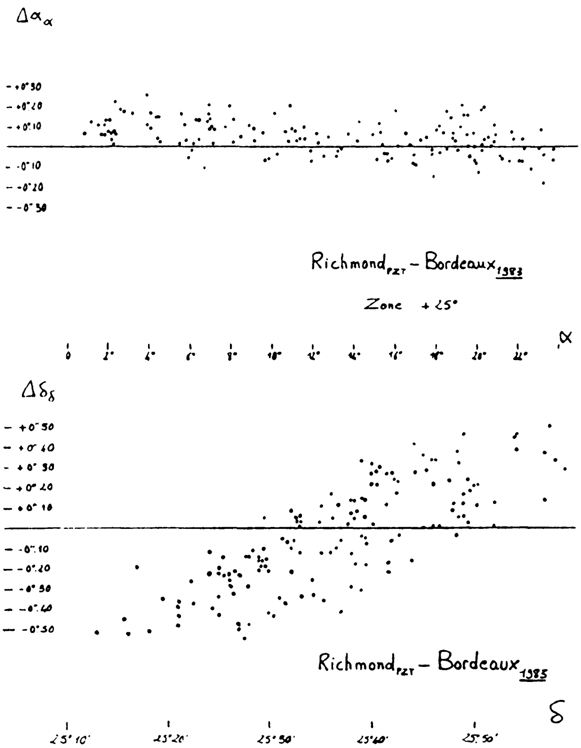

Figure 3. Richmond P.Z.T. minus Bordeaux.

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2.2. Comparison with the 1983 Brorfelde catalogue

The last Brorfelde catalogue (Helmer *et al.* 1984) observed with the fully automatic Carlsberg meridian circle before its transfer to La Palma contains 211 NPZT stars common with our new catalogue. The standard deviations, star by star, are

$$0.09'' \text{ in } \alpha \text{ and } 0.13'' \text{ in } \delta.$$

Taking into account that the precision of a Brorfelde position is 0.08" in the two coordinates, this agreement is excellent (suggesting only that our accuracy could be slightly superior to our precision in declination, say 0.09" at the very worst...).

2.3. Deviation from the FK4

During each observing night, deviations (O – C) were obtained for the FK4 reference stars used in the differential determination of the constants of the instrument. Mean deviations (Bordeaux – FK4) were computed for 778 FK4 stars from 11700 individual (O – C), i.e. about 15 per star. Figures 4 and 5 show the individual deviations which represent quite well the accidental errors of the FK4 system at the mean epoch 1982.5 (more recent observation nights have been also used). These curves demonstrate the present state of the primary reference system : of course systematic errors are rather small but some well-known "butterfly" stars show inacceptable deviations and the FK4 standard dispersion appears to be

$$0.12'' \text{ in } \alpha \text{ and } 0.14'' \text{ in } \delta.$$

From our first NPZT observations (Mazurier *et al.* 1973), we had found 0.10" and 0.13", respectively.

We must therefore emphasize that publication of the FK5 catalogue with individual star positions and proper motions has become the most urgent need for all astrometrists.

3. FAINT STARS

In order to test the accuracy of our instrument for faint objects we have observed a program of 378 nearby stars from the Gliese catalogue, selected by C. Turon for the HIPPARCOS mission (K and M, except giants and supergiants, not included in the AGK3). The mse for one observation were

$$0.12'' \text{ in } \alpha \text{ and } 0.19'' \text{ in } \delta \qquad \text{for } 9.0 < m_V < 11.0$$
$$0.13'' \text{ in } \alpha \text{ and } 0.19'' \text{ in } \delta \qquad \text{for } 11.0 < m_V < 12.5.$$

We encountered problems with double stars and also with bad coordinates and/or proper motions in the Gliese catalogue : we were not able to find 2 % of these stars with V < 12.0 (5 of the 29 program stars with $12.0 \leqslant V < 12.5$ were not found).

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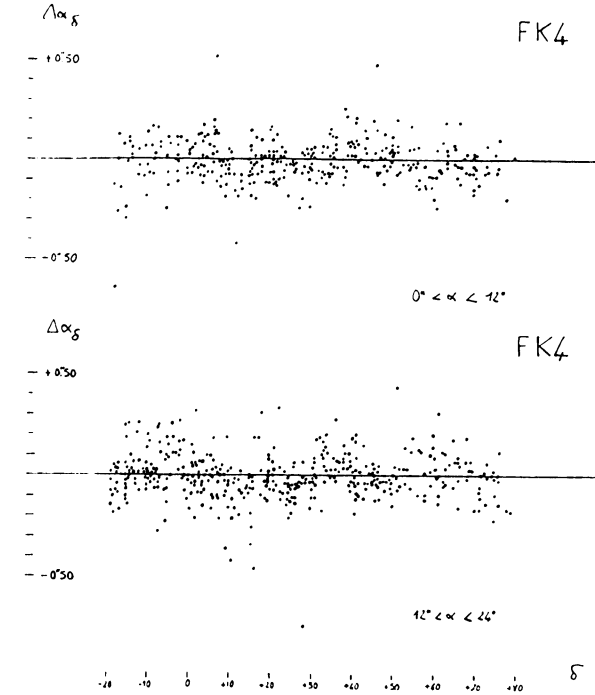

Figure 4. FK4 deviations $\Delta\alpha_\delta$.

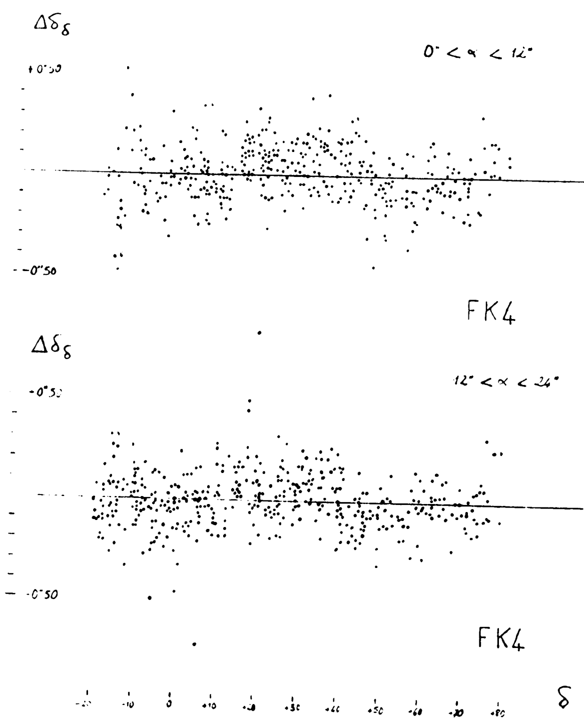

Figure 5. FK4 deviations $\Delta\delta_\delta$.

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Furthermore, 99 radio stars from the HIPPARCOS list (De Vegt 1983) were observed last year with a standard error of 0.11" in α and 0.18" in δ (11 observations per star).

4. SOLAR SYSTEM OBJECTS

We have succeeded in making the following observations :

Mars : 27 transits in 1982. A study of the phase effect in cooperation with the Paris Observatory (Chollet 1982) is in progress.

Uranus : 43 transits in 1982-1983.

Neptune : 32 transits in 1982-1983.

Galilean satellites : 57 transits in 1982-1983. An interesting possibility is the tracking of two satellites during each planet transit, the first before meridian and the second after.

Saturn satellites : Titan and Iapetus.

Minor planets for the HIPPARCOS program : 433 observations of 36 asteroids in 1983.

(51) Nemausa. In cooperation with L.K. Kristensen, (51) Nemausa was regularly observed in 1982 (17 positions) and 1983 (32 positions) in order to improve the FK5 equinox correction. The occultation of the star 14 Psc by Nemausa on 1983 September 11 provided a good opportunity to check the accuracy of our instrument. Prediction of the occultation derived from 10 Bordeaux observations of Nemausa and the star was off by only 0.04" (Dunham 1983).

5. FUTURE PROGRAMS

In the frame of the HIPPARCOS Input Catalogue preparation, we plan to observe about 5000 Northern faint stars during the period 1984.5 - 1987.0.

Another urgent task will be the re-observation of a list of AGK3R stars with bad observational history in cooperation with the U.S. Naval Observatory.

Furthermore we have to keep in mind that about 200000 stars have been proposed for the HIPPARCOS mission and that only 100000 of them will finally be selected. For a number of the 100000 "remaining" stars, only proper motions are required in the proposals. Automatic meridian circles would be quite convenient for such a program if first epoch positions were available. This "HIPPARCOS supplement" could be an alternative to the Tycho Space option, especially in the range $10 < V < 12.5$.

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Discussion:

HUGHES: Which Richmond PZT catalogue did you use for comparison? I ask this since some revisions have been made relatively recently.
REQUIEME: Dr. Monger sent me the last version at my request.
HUGHES: Have you graphs of the comparisions with Washington?
REQUIEME: Yes.
HØG: Before you start observation of the 200000 HIPPARCOS stars, as you intend, I would propose that you observe the 40000 stars for which INCA only gives a standard error of 1". If you could do this before the mission it would be very useful.
de VEGT: Your result on individual deviations of FK4 stars is well confirmed by astrograph observations we have made. Individual FK4 stars may be off by as much as 0".5 (for example, α Ori).
SCHWAN: I would like to comment on the FK4 star 667. This star has shown up in all our catalogues as a discordant star. The star is listed in the IDS as a multiple system and an analysis of the residuals Catalogue-FK4 for catalogues later than about 1900 has clearly shown orbital motion. Observations by speckle interferometry may be helpful for determining an accurate orbit which is obviously needed for the computation of an accurate ephemeris.
YE: Did you observe a relationship between the declination of the stars and the precision?
REQUIEME: The rms errors do vary in the various declination zones or rather with the zenith distance.